Life-Cycle Impact Analysis: LED Manufacturing and Performance

The report *LED Manufacturing and Performance* covers the second part of a larger U.S. Department of Energy (DOE) project to assess the life-cycle environmental and resource costs in the manufacturing, transport, use, and disposal of light-emitting diode (LED) lighting products in comparison to traditional lighting technologies.

Part 1 of the DOE assessment effort reviewed existing life-cycle analysis (LCA) literature to determine the range of energy consumption and down-stream energy savings. The report compared life-cycle energy consumption of an LED lamp product to incandescent lamp and compact fluorescent lamp (CFL) technologies. The Part 1 report concluded that both LEDs and CFLs are similar in energy consumption, and that the use phase (in contrast to the manufacturing and transport phases) consumes the most energy over the life cycle of these products.

Part 2 of the project produced a more detailed and conservative assessment of the manufacturing process of an LED product and provided a comparative LCA with other lighting products, based on improved manufacturing analysis and taking into consideration a wider range of environmental impacts. The study aims to understand the impacts of the manufacturing process for a white-light LED lamp. The LCA looked at the impacts associated with a representative LED lamp and compared them to a CFL and an incandescent lamp. The comparison took into account the LED lamp as it is now in 2012 and then projected forward what it might be in 2017, accounting for some of the anticipated improvements in LED manufacturing, performance, and driver electronics. The Part 2 study confirmed that energy-in-use is the dominant environmental impact, with the 15-watt CFL and 12.5-watt LED lamp performing better than the 60-watt incandescent lamp.

A COMPREHENSIVE LOOK

The DOE life-cycle environmental analysis of LED lighting products includes three parts:

Part 1 reviewed existing LCA literature to determine the range of energy consumption and down-stream energy savings

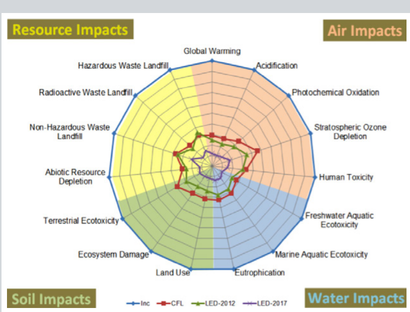
Part 2 is a comprehensive LCA, based on a detailed and conserva-tive approach to characterizing LED manufacturing

Part 3 will focus on disassembly and chemical testing

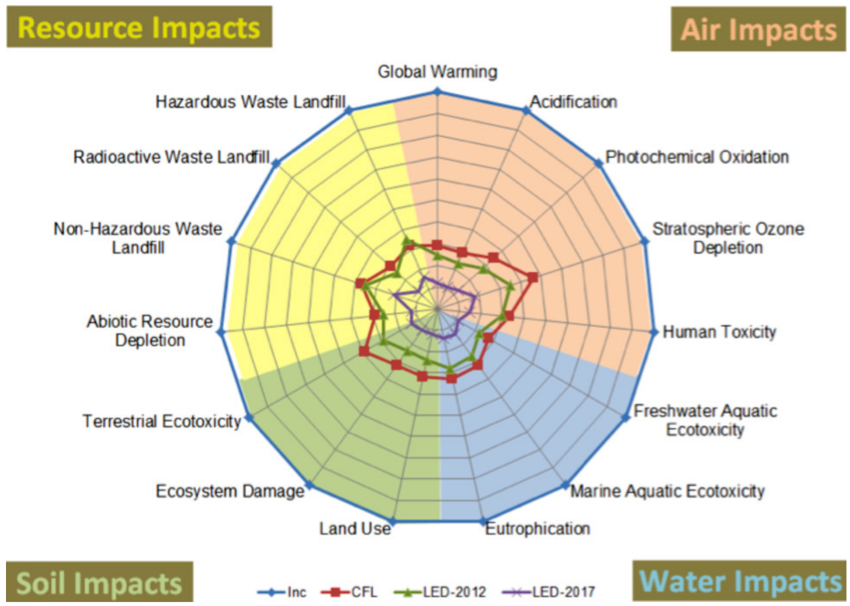
KEY FINDINGS

The figure on page 2 shows that the incandescent lamp has the highest impact of all the lamps considered, primarily because of low efficacy and the resulting large quantities of energy required to produce light. Energy

AT A GLANCE



In order to evaluate the fifteen impact measures of interest across the four lamp types considered, "spider" graphs were prepared. Each of the fifteen impact categories become a spoke in the web, and the relative impacts of each lamp type are plotted on the graph. The lamp type having the greatest impact of the set analyzed (incandescent, in this case) defines the scale represented by the outer circle at the greatest distance from the center of the web. The other products are then normalized to that impact, so the distance from the center denotes the severity of the impact relative to the incandescent lamp. See page 2 for more details.



needed to manufacture product replacements to span the (longer) rated life of an LED lamp or CFL is also a factor. Generating the higher amount of electric energy consumed per unit of light output causes substantial environmental impacts and results in the incandescent lamp being the most environmentally harmful across all fifteen impact measures.

While it has substantially lower impacts than the incandescent lamp, the CFL is slightly more harmful than the 2012 integrally ballasted LED lamp across all criteria except one—hazardous waste landfill, where manufacturing the large aluminum heat sink used in the LED lamp causes the impacts to be slightly greater for the LED lamp than for the CFL. The best performing light source is the projected LED lamp in 2017, which takes into account several prospective improvements in LED manufacturing, performance, and driver electronics.

RECOMMENDATIONS

Because of the dominant role of energy consumption during the use phase found by the LCA, continued focus on efficacy targets, cost reduction, and market acceptance is appropriate. The greatest environmental impact after energy-in-use for the LED sources comes from manufacturing the aluminum heat sink, which would be reduced in size as the efficacy increases, and more of the input wattage is converted to useful lumens of light (instead of waste heat). The heat sink is the main reason that the LED currently exceeds the CFL in the category of hazardous waste to landfill, which is driven by the upstream energy and environmental impacts from manufacturing the aluminum from raw materials. Although end-of-life was evaluated in a conservative way for this report, recycling efforts could further reduce the adverse impact of manufacturing the aluminum heat sink.

The important finding from the LCA study is not minor relative differences between the LED lamp and the CFL, but the significant reduction in environmental impacts from replacing an incandescent lamp with a more efficient product. Reductions on the order of 3 to 10 times are possible across the indicators by transitioning the market to new, more efficacious light sources.

The full report with more detailed results can be downloaded at www.ssl.energy.gov/tech_reports.html. Part 3 of the project, focused on disassembly and chemical testing, will be published in late 2012.